Remembering change: The critical role of recursive remindings in proactive effects of memory

By: Christopher N. Wahlheim, Larry L. Jacoby

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Abstract:

In three experiments, we examined the role of the detection and recollection of change in proactive effects of memory in a classic A–B, A–D paradigm. Participants studied two lists of word pairs that included pairs repeated across lists (A–B, A–B), pairs with the same cue but a changed response (A–B, A–D) in the second list, and control pairs (A–B, C–D). The results revealed that performance on A–B, A–D pairs reflected a mixture of facilitation and interference effects. Proactive facilitation occurred when changes in responses were detected and recollected, whereas proactive interference occurred when change was not detected or when it was not recollected. We describe detecting change as involving recursive remindings that result in memory for the List 1 response being embedded in the representation of memory for the List 2 response. These embedded representations preserve the temporal order of the responses. Our findings highlight the importance of detection and recollection of change for proactive effects of memory.

Keywords: Change detection | Proactive effects | Interference | Facilitation | Recursive remindings

Articles:

A politician changes his position on an important issue in a way that contradicts an earlier-held position and hopes that the change will go unnoticed. If noticed, he fears that having made the change in position will result in his being labeled as a “flip-flopper.” However, even if the change is unnoticed, there is reason to expect an influence of memory for the earlier-held position on that for the later-held position because of proactive interference. In the language of paired-associate learning, the situation can be represented as A (politician)–B (earlier position) followed by A (politician)–D (changed position). *Proactive interference* refers to the deleterious effects of memory for A–B on later recall of A–D. Such interference has been found in laboratory experiments examining memory for paired associates and has been attributed to response competition (e.g., Postman & Underwood, 1973). If the A–B association is a strong one, memory for the original response (B) is said to compete with the changed response (D) and to produce proactive interference by serving as a source of errors during attempts to recall the changed response.

When is an audience likely to become aware of change in a politician's position, and what are the effects of awareness of this change on subsequent memory? For change to be noted and remembered, it is necessary that a later event *remind* one of the corresponding earlier event(s). Again in the language of memory for paired associates, it is important that one be reminded of A–B by the presentation of A–D. For the self-contradicting politician, the change in position with regard to an issue is more likely to be detected if the initial position was repeatedly stated, making it more easily remembered. Being reminded of the earlier position (A–B) by presentation of the changed position (A–D) might further enhance memory for the earlier position. More importantly for the present purposes, such change detection might also be followed by recollection of the change and, thereby, enhance memory for the later-held position (i.e., proactive facilitation).

Continuing the example of contradictory positions held by a politician, the underlying memory representation could take the form of "Politician A, who earlier held position B, now holds position D." The form is one of recursion, which serves to embed the earlier event into the memory representation for the later event. Corballis (2011) argued that memory is recursive and that its being so serves as the origin of language and thought. A recursive representation creates dependence between the original and changed responses, making it likely that they will later be recalled together. Also, as was noted by Hintzman (2011), recursive reminding preserves the temporal order of events. Because of these effects, we argue that recursive reminding can result in proactive facilitation of memory for the changed response (A–D). Although recursive remindings are sometimes spontaneous (Hintzman, 2011), we hold that individual differences and task demands also play a role in the occurrence of recursive remindings (e.g., Jacoby, 1974).

In the experiments reported here, we examined the effects of detection and memory for change with paired associates. To anticipate the results, we show that detection and memory for change produced proactive facilitation. Proactive facilitation is shown by memory for a second event (A–D) being superior to the memory that would be observed if the first event (A–B) had not occurred (i.e., a control condition). Increasing the number of presentations of A–B had the effect of increasing detection of change and, thereby, produced increased memory for A–D. In the absence of detection and memory for change, prior presentation of A–B reduced later memory of A–D (i.e., proactive interference). Before describing our experiments, we will briefly review the relevant literature.

Prior research has shown the importance of remindings for memory of the temporal order of events and for effects of repetitions. Judgments of recency are superior for related (e.g., *queen–king*) as compared to unrelated (e.g., *spider–table*) words (Hintzman, 2010; Tzeng & Cotton, 1980; Winograd & Soloway, 1985). This effect on memory for temporal order has been explained as being due to the presentation of the second member of a related pair (e.g., *king*) reminding participants of the first member of the pair (e.g., *queen*). Remindings also play a role in frequency judgments (Hintzman, 2004) and in memory for semantic associates (e.g., Benjamin & Ross, 2010). For each of these cases, remindings are said to have their effect by embedding memory for the earlier event into that of the later event. Brain regions such as the left posterior hippocampus and parahippocampal cortex have been shown to be associated with individual differences in response integration and susceptibility to retroactive interference, suggesting potential biological correlates of remindings (e.g., Kuhl, Shah, DuBrow, & Wagner, 2010).

Of particular relevance to the present experiments, remindings are important for finding facilitative effects of repetitions. An early example of this can be seen in the paired-associate learning experiments by Asch, Rescorla, and Linder, as reported by Asch (1969). In their experiments, a single well-learned pair from a first list was included in a second list of pairs that was presented after a delay. This form of presentation discouraged participants from recognizing the repetition in List 2, resulting in a small percentage of participants doing so. Participants who did not recognize the repeated pair as being such showed no advantage in memory for the repeated pairs, as compared to new pairs that only appeared in List 2. In contrast, participants who did recognize the repetition showed a facilitative effect. Furthermore, when another group was told about the repetition and encouraged to notice it prior to studying List 2, nearly every participant did so and showed a facilitative effect of repetition. Encouraging participants to notice the repetition can be described as encouraging them to engage in reminding. Similarly, Appleton-Knapp, Bjork, and Wickens (2005) showed the importance of reminding for the effect of spacing repetitions on memory for advertisements. Their results showed that study-phase retrievals (i.e., remindings) contributed to the benefit of spacing repetitions. At long spacings of repetitions, inducing variations in ads by changes in formatting or content reduced the effects of repetition by decreasing remindings of earlier variants of an ad (for further evidence of the importance of remindings for the effects of spacing repetitions, see Benjamin & Tullis, 2010; Johnston & Uhl, 1976).

The above experiments provided evidence that judgments of temporal order and repetition effects are facilitated by remindings that result in detection and memory of consistency among events. Similarly, detection and memory for change might rely on reminding and produce facilitation effects. Experiments examining memory for paired associates in A–B, A–D paradigms have typically found proactive interference. However, several studies have shown that performance on A–B, A–D pairs does not differ from, or is even better than, performance on controls (e.g., Barnes & Underwood, 1959; Bruce & Weaver, 1973; E. Martin, 1968; Postman, 1964; Robbins & Bray, 1974). We argue that these differences can be explained by variation in the probability of remindings and describe advantages of our recursive-remindings account over a mediation account of facilitation effects (e.g., Barnes & Underwood, 1959).

Barnes and Underwood (1959) found retroactive facilitation effects by varying the similarity of responses in two lists. For an A–B, A–B′ paradigm, the responses in List 2 were synonyms of the responses in List 1 (e.g., *afraid*, *scared*), whereas in an A–B, A–D paradigm the responses were unrelated. At test, participants recalled responses from both lists. For the A–B, A–D paradigm, recall of List 1 declined with increased numbers of trials on List 2, showing retroactive interference. In contrast, for the A–B, A–B′ paradigm, recall of List 2 was nearly perfect after one trial, and recall of List 1 did not decline appreciably across increases in List 2 trials. Facilitation in the A–B, A–B′ paradigm was explained as resulting from participants taking advantage of the strong associations between responses by using List 1 responses to mediate their learning of the List 2 responses. That is, List 2 learning was said to be of the form A–B–B′. Support for this mediation account was provided by the finding that the List 1 response was more often recalled first, as would be expected if learning of the List 2 response was mediated by the List 1 response. Furthermore, nearly all participants reported using the List 1 response to help them remember the List 2 response.

It is important that participants were aware of using List 1 responses to aid their memory of List 2 responses in the Barnes and Underwood (1959) experiment. R. B. Martin and Dean (1964) provided direct evidence of the importance of such awareness for finding effects that have been attributed to mediation by associations. In their experiment, participants learned a list of A–B pairs and then learned a second list that contained pairs for which the response was a strong associate of a List 1 response (i.e., Barnes & Underwood's A–B, A–B′ condition), as well as pairs for which the responses in the two lists were unrelated (i.e., Barnes & Underwood's A–B, A–D condition). Following the test of the second list, participants described how they had learned each pair. Results revealed an advantage for the A–B, A–B′ pairs over A–B, A–D pairs only for A–B, A–B′ pairs whose learning was reported as relying on memory of the List 1 response. R. B. Martin and Dean distinguished between explicit (aware) and implicit (unaware) mediation and concluded that their results showed no evidence of implicit mediation. The importance of awareness has led some (see Hall, 1971, pp. 396–398) to doubt the existence of associative mediation of the sort credited for effects of strong associations between responses (e.g., Russell & Storms, 1955).

As an alternative to a mediation account, facilitation of memory for a changed response can be described as resulting from detection and later recollection of change. Doing so explains the importance of awareness of the relationship between the original and changed responses. By a memory-for-change account, detection of change results from study-phase remindings that are available to conscious awareness. Awareness of change is important for facilitating performance because what is thought about an item during its presentation is what is encoded in memory. When change is detected, the earlier pair (A–B) is embedded into a representation of the later pair (A–D), preserving the order of the two responses (cf. Hintzman, 2010). Recollection of the recursive reminding at test results in proactive facilitation. In contrast to mediation accounts of proactive facilitation (e.g., Barnes & Underwood, 1959), the memory-for-change account predicts that proactive facilitation will not require the presence of a strong associative relationship between responses. Although it is likely necessary for there to be some potential relationship between responses in order to produce detection of change along with recursive encoding, we predict that proactive facilitation can be found even when there is only a very weak or no preexperimental association between responses.

Whereas memory for change provides a means of preserving the order of events, a mediation account of proactive facilitation does not do so. A strong extraexperimental association between B and D does not by itself preserve information regarding the lists in which the responses occurred. Indeed, one might expect that a strong association between responses would reduce list differentiation and, thereby, result in List 1 responses more often intruding when participants are asked to recall List 2 responses. Results of this sort were reported by Young (1955). In Young's experiments, the similarity of adjectives paired with a cue varied from low to medium to high. In a test of the proactive effects of earlier presentations, the number of intrusions of adjectives from earlier lists increased with the similarity of adjectives.

We forward a dual-process model that holds that proactive facilitation originates from recursive remindings that embed memory for a List 1 pairing (A–B) in memory for a List 2 pairing (A–D), just as described for the self-contradicting politician, rather than from mediation between responses. In doing so, we build on evidence showing the importance of awareness of repetition (remindings) for the magnitude of repetition effects (e.g., Appleton-Knapp et al., 2005; Asch, 1969), but focus on the detection of change rather than on the detection of consistency (e.g., repetition). In the absence of detection and recollection of change, participants are held to rely on associative strength as a basis for responding (e.g., Postman & Underwood, 1973), with the result that proactive interference is observed, whereas recollection of change results in proactive facilitation.

It is likely that a dual-process model is necessary to account for the effects of repetition and change. In that vein, Hintzman (2004) convincingly showed that judgments of frequency depend on recursive remindings. However, very dense amnesics also show an effect of repetition on frequency judgments, although they are unable to engage in recollection of the sort necessary to profit from remindings. For amnesics, increasing the frequency of presentation of an item increases both its judged frequency and recency, as does increasing the recency of presentation of an item. These results suggest that amnesics make both recency and frequency judgments on the basis of overall memory strength (Huppert & Piercy, 1978) and support the possibility that repetition can result in a strengthening of memory that has relatively automatic effects, as well as in recursive remindings that rely on recollection.

It is difficult to separate the effects of recollection from those of automatic influences on frequency and recency judgments, because both serve to enhance performance. In contrast, arranging a situation such that the automatic influences of memory produce an effect that is opposite to that produced by recollection has important advantages as a means of gaining evidence to support a dual-process model of memory (e.g., Jacoby, 1991; for a review, see Yonelinas & Jacoby, 2012). In this vein, strong support for a dual-process model would be provided by findings that a change produces proactive facilitation when the change is detected and recollected but produces an opposite effect (i.e., proactive interference) in the absence of detection and recollection.

According to our dual-process model, the overall later recall of changed responses in an A–B, A–D paradigm reflects a mixture of proactive facilitation originating from recollection of change, encoded as a recursive reminding, and proactive interference originating from a more automatic basis for responding that reflects associative strength. To gain support for this claim, what is needed are means of measuring the detection and recollection of change. Next, we describe the procedure of Experiment 1 in order to introduce the measures of detection and recollection of change employed in our experiments.

In our experiments, we employed a within-participants manipulation of the correspondence between List 1 and List 2 pairs. List 2 included pairs that were the same as those in List 1 (A–B, A–B), pairs for which the response was changed between lists (A–B, A–D), and pairs for which neither member of the pair had appeared in List 1 (A–B, C–D). In contrast to the pairs used in investigations of mediation effects (e.g., Barnes & Underwood, 1959), the right-hand members of A–B and A–D pairs were, at most, weak preexperimental associates of one another. A–B pairs were presented either two or four times in List 1. Manipulating the relation between the pairs in the two lists allowed us to investigate change detection and memory for change. To measure detection of change during List 2, participants were instructed to indicate whether they noticed that a response paired with a cue presented in List 1 had changed between lists (i.e., A–B, A–D pairs). Furthermore, they were told to recall the List 1 response when they detected such a change.

At test, participants were provided with the left-hand member of each pair presented in List 2 and asked to recall the right-hand member of that pair. To measure recollection of change at the time of test, we employed a remindings-report procedure. Participants were instructed that if another word came to mind prior to or simultaneously with a word that they produced as being a List 2 response, they were to report the word that came to mind. Reporting a List 1 response as having come to mind was treated as indicating that a reminding had occurred during List 2 study and was recollected at test. The rationale for doing so was that if change was recollected, the List 1 response would be expected to come to mind prior to or simultaneously with the List 2 response because of the dependency created by the underlying recursive representation. Returning to the example of a self-contradicting politician, the suggestion is that if asked to recall the politician’s current position, the prior position would likely come to mind first or simultaneously with the current position—that is, the “flip” will come to mind prior to the “flop.”

We expected that the accessibility of List 1 responses would increase with List 1 presentations, thus producing a higher probability of change detection for A–B, A–D items during the presentation of List 2, along with a higher probability of recollection of change as measured by the remindings-report procedure. Proactive facilitation was expected when change was recollected, and proactive interference resulting from automatic influences of memory was expected when change was not recollected.

To gain evidence of the importance of recollection of change, we conditionalized the probability of List 2 recall in the A–B, A–D condition on the presence versus absence of change recollection as measured by the remindings-report procedure. Reliance on conditionalized results carries the danger that the results obtained would be influenced by item selection effects. In this vein, a modestly positive correlation has been found in the rates of acquisition of first- and second-list responses to the same stimulus in the A–B, A–D paradigm (Postman & Stark, 1969; Wichawut & Martin, 1971). This correlation presumably reflects differences among stimuli in the ease of their recognition and/or the ease with which associations to other items can be formed. For our results, effects obtained by conditionalizing recall on memory for change might reflect such item differences. Consequently, we employed hierarchical regression analyses to show that for each of our experiments, memory for change had effects beyond those produced by item differences.

We also employed hierarchical regression analyses to examine whether individual differences in the probability of recollection of change were correlated with List 2 recall. As we will describe in the General Discussion, people likely differ in the extent to which they detect and remember change. Individual differences in detection and memory for change have not previously been a focus for investigation but are likely to be important for performance on a variety of tasks.

Experiment 1

Method

Participants

A group of 40 Washington University students participated in exchange for course credit or $10/h. All participants were tested individually.

Design and materials

A 3 (item type: A–B, A–B vs. A–B, C–D [control] vs. A–B, A–D) × 2 (List 1 presentations: four vs. two) within-participants design was used. The design was fully crossed with the exception of control pairs, because they were not subjected to the manipulation of List 1 repetitions. The critical materials consisted of 100 three-word sets that included a cue word (e.g., *knee*) and two responses associated with the cue (e.g., *bone*, *bend*). These sets were drawn from Jacoby (1996) and Nelson, McEvoy, and Schreiber (1998). The responses in each set were orthographically related because they were originally designed to create fragments that could be completed by either of the two responses (e.g., *b_n_* could be completed by *bone* or *bend*). The forward and backward associative strengths between responses were low, on average (forward, $M = .03$, $SD = .08$; backward, $M = .02$, $SD = .05$), as indexed by Nelson et al. Five groups of 20 sets served as the critical items. Each group was matched on the lengths and frequencies of cues and responses. These groups served equally often in each within-subjects condition across participants. The rotation of groups through conditions produced five experimental formats. An additional three groups of three sets served as buffers in List 1 and as practice for the change detection task in List 2, and another three groups of two sets served as buffers in List 2 and practice test pairs. The assignment of these pairs to conditions remained constant across formats.

List 1 consisted of 90 word pairs (e.g., *knee–bone*) that included six buffers to be used for the List 2 practice phase, four intermixed pairs to be used as buffers in List 2 and as practice test pairs, and 80 critical pairs. The six buffers appeared once each, whereas for the remaining pairs, half appeared twice and the other half appeared four times, for 258 total presentations. The List 2 practice phase contained nine pairs (three of each item type), and List 2 included 106 pairs that consisted of six buffers and 100 critical pairs. Two buffers served in primacy positions and four served in recency positions. Twenty critical pairs were included in each within-participants condition. The A–B, A–B pairs consisted of the same pairs in Lists 1 and 2 (e.g., *apple–core*, *apple–core*); the A–B, C–D control pairs appeared exclusively in List 2 (e.g., *lamb–wool*);

and the A–B, A–D pairs consisted of the same cues in Lists 1 and 2 with different responses (e.g., *knee–bone*, *knee–bend*). At test, the six buffer pairs were used for practice, and the test included all 100 critical pairs.

Procedure

List 1 pairs appeared in a fixed random order with the restriction that none from the same condition appeared consecutively more than three times. Pairs were presented for 2 s each, followed by a 500-ms interstimulus interval (ISI). Participants were told that their task was to read pairs quickly because we were interested in their reading times.

Participants first completed a List 2 practice phase prior to the presentation of List 2. In both phases, pairs appeared randomly with the same restrictions as in List 1. Participants' first task was to study pairs for as long as was necessary to learn pairs completely for an upcoming test. Their second task was to indicate pairs for which responses had changed (A–B, A–D) and to recall the List 1 response (B). Boxes labeled "next" and "right word changed" appeared below pairs. Participants were told to click "next" when they had completed studying an unchanged pair or to click "right word changed" when they noticed a changed pair. After indicating a change, participants attempted to recall the List 1 response aloud, and their responses were recorded by an experimenter. The pair then remained on the screen with only the "next" box. Participants continued studying the pair until it was learned, at which point they clicked "next" to move on.

At test, cues (the left-hand member of List 2 pairs) appeared randomly with the same restrictions as for the earlier lists. Participants were told to retrieve the List 2 responses and to report whether another response came to mind prior to or simultaneously with their final response. Pilot work showed that participants infrequently reported two words as coming to mind simultaneously. However, we assumed that these instances provided the same indirect evidence for retrieval of List 1 responses during List 2 study as did instances in which another word was reported as coming to mind prior to the recalled response. Consequently, participants were told that if this happened, they should first report the response that they thought was from List 2 and then report the other response as coming to mind first. The cues remained on the screen until the responses were recorded by the experimenter. Next, the message "Did another word come to mind?" appeared above boxes labeled "yes" and "no." When participants clicked "yes," the message, "What word came to mind?" appeared, and responses were recorded by an experimenter. When participants clicked "no," the program advanced to the next item.

Results and discussion

For all experiments, the reported effects were significant below $\alpha = .05$ unless otherwise noted. When present, variation in the degrees of freedom for conditional analyses was due to the exclusion of participants who did not have at least one observation in each cell.

Table 1 shows that recall performance for A–B, A–B pairs was better following four than following two List 1 presentations (.88 vs. .82), $t(39) = 3.46$, and that overall recall was greater for A–B, A–B than for control pairs (.85 vs. .58), $t(24) = 12.48$. More important, recall of A–B, A–D pairs did not differ between List 1 presentation conditions (.57 vs. .58), $t(24) = 1.96$, nor did recall differ between A–B, A–D and control pairs (.58 vs. .58), $t < 1$. The lack of differences in the latter two comparisons suggests the presence of offsetting effects of proactive facilitation and interference on A–B, A–D pairs resulting from a mixture of the presence and absence of remindings.

Table 1 Probability of recalling List 2 responses as a function of item type and List 1 presentations: Experiments 1–3

List 1 Presentations	**Item Type**		
	A–B, A–B	**Control***	**A–B, A–D**
Experiment 1			
Four	.88 (.02)	.58 (.03)	.57 (.04)
Two	.82 (.02)	.58 (.03)	.58 (.04)
Experiment 2			
Three	.83 (.03)	.64 (.04)	.54 (.05)
Experiment 3			
Four	.79 (.03)	.41 (.04)	.44 (.04)
Two	.68 (.04)	.41 (.04)	.38 (.04)

*Control pairs were not subjected to the manipulation of List 1 presentations, so the values for those pairs presented in Experiments 1 and 3 above are duplicates. Standard errors of the means are presented in parentheses.

Effects of detection and recollection of change

Detection of change for A–D pairs during presentation of List 2 was far less than perfect, but it was greater after four than after two List 1 presentations of A–B pairs (.76 vs. .62), $t(39) = 6.54$. Participants rarely indicated that responses had changed for A–B, A–B (.01) or control (.03) pairs. When change was detected, participants were extremely accurate in recalling the List 1 response, and there was a marginal advantage following four as compared to two List 1 presentations (.90 vs. .85), $t(39) = 1.71$, $p = .096$. For the later test of List 2 pairs, the remindings report procedure revealed that the probability of change recollection (Table 2) was lower than the probability of detecting change during List 2. However, as with change detection, recollection of change was higher after four than after two List 1 presentations (.42 vs. .38), $t(24) = 1.88$, $p = .03$ (one-tailed). Note that the majority of responses reported as coming to mind first were from List 1 (83 %), with the rest being from List 2 (8 %) or from outside the experiment (9 %).

Table 2 Probability of a response coming to mind prior to responses recalled at test on A–B, A–D pairs as a function of response type and List 1 presentations: Experiments 1–3

List 1 Presentations	**Response Type**		
	List 1	**List 2**	**Extra List**
Experiment 1			
Four	.42 (.04)	.05 (.02)	.04 (.04)
Two	.38 (.04)	.03 (.01)	.05 (.01)
Experiment 2			

Three	.32 (.05)	.04 (.01)	.06 (.01)
Experiment 3			
Four	.31 (.05)	.05 (.02)	.06 (.02)
Two	.22 (.04)	.03 (.01)	.06 (.02)

Standard errors of the means are presented in parentheses.

The corresponding effect of List 1 repetitions on detection and recollection of change provides support for the validity of the remindings report procedure as a means of measuring recollection of change. Additional evidence that the remindings report procedure measured recollection of change was provided by the finding that the conditional probability of a List 1 response coming to mind first was dramatically higher when change was detected during the presentation of List 2 than when it was not (.52 vs. .04), $F(1, 37) = 137.23$, $\eta_p^2 = .79$. Furthermore, List 1 responses came to mind first almost exclusively when List 1 responses had been recalled rather than not recalled after detection of change during List 2 (.60 vs. .05), $F(1, 21) = 144.75$, $\eta_p^2 = .87$. Neither of these effects interacted with List 1 presentations, *F*s < 1.98. These results provide strong evidence that the probability of List 1 responses coming to mind prior to recalled responses at test reflected recollection of change detection during List 2.

To explore the mixture of proactive facilitation and proactive interference effects on performance in the A–B, A–D condition, we examined recall conditionalized on detection and recollection of change. Recall was better when change was detected in List 2 than when change went undetected (.60 vs. .47), $F(1, 37) = 8.92$, $\eta_p^2 = .19$. In addition, Fig. 1 shows that recall was dramatically higher when change was recollected at test (a List 1 response preceded the recalled response) as compared to when change was not recollected (no response came to mind first; .88 vs. .42), $F(1, 35) = 256.88$, $\eta_p^2 = .88$. We found no significant effects of, or interactions with, List 1 presentations, *F*s < 1.46. Further analyses revealed that recall was higher for A–B, A–D pairs when List 1 responses came to mind first as compared to controls (.88 vs. .59), $t(35) = 12.56$, and controls were higher than A–B, A–D pairs for which no response was reported as coming to mind first (.59 vs. .42), $t(35) = 5.45$. That is, proactive facilitation was observed for A–B, A–D pairs when remindings were recollected, and proactive interference was observed when they were not.

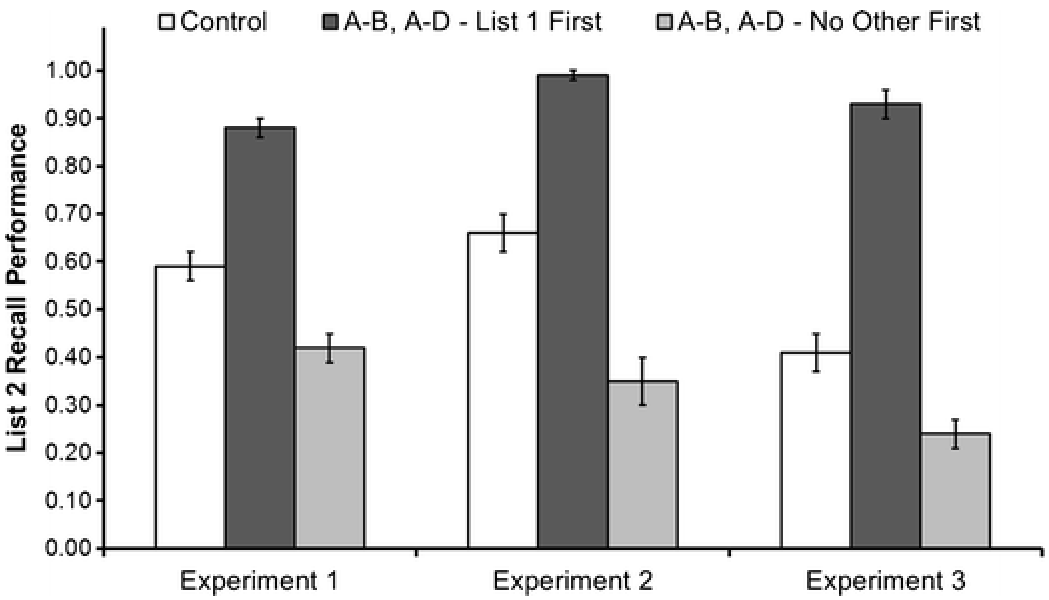

Fig. 1 Probabilities of correct recall of List 2 responses for control pairs and for A–B, A–D pairs, conditionalized on whether a List 1 response was reported as coming to mind first or whether no other response was reported as coming to mind first. Recall of A–B, A–D pairs is collapsed across List 1 presentations in Experiments 1 and 3, because that manipulation produced no differences

As is shown in Fig. 2, the effect of detecting change was dependent on its later recollection, $F(2, 54) = 54.36$, $\eta_p^2 = .67$. A–B, A–D performance when change was detected and a List 1 response came to mind first was better than when change was not detected and no other response was reported as coming to mind first (.88 vs. .52), $t(27) = 7.71$. More interesting, performance on pairs for which change was earlier detected but not recollected (no other response came to mind first at test) was actually lower than performance on pairs for which change was not detected and no other response came to mind first (.35 vs. .52), $t(27) = –2.73$. There was no effect of, or interaction with, List 1 presentations, Fs < 1.

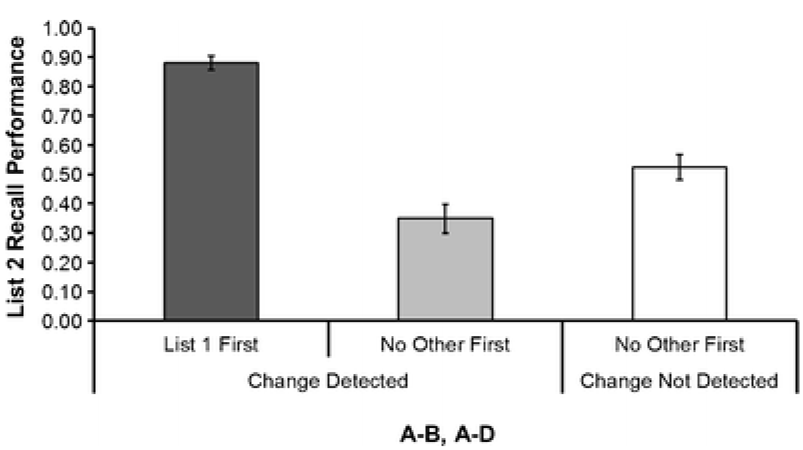

Fig. 2 Probabilities of correct recall of List 2 responses for A–B, A–D pairs in Experiment 1, conditionalized on change detection and whether a List 1 response was reported as coming to mind first or whether no other response was reported as coming to mind first

The poorer recall performance produced by detection of change followed by failure to recollect change is informative with regard to the effects of the retrieval of List 1 responses during the presentation of List 2. Detection of change was often accompanied by recall of the corresponding List 1 response, which would be expected to enhance its subsequent recall and, thereby, increase its effectiveness as a competitor for the List 2 response. Bishara and Jacoby (2008) found that practice retrieving the List 1 response in an A–B, A–D paradigm increased proactive interference for older adults, but did not do so for young adults. These results were described as resulting from an effect of retrieval practice on an automatic influence of memory that comes into play when recollection fails, which was more common for older than for younger adults (e.g., Hay & Jacoby, 1999). In line with the results reported by Bishara and Jacoby 2008, retrieval practice that accompanied detection of change in the present experiment increased proactive interference only when change was not recollected. The finding of opposite effects of detecting change, dependent on its later recollection, joins earlier results in providing support for a dual-process model that distinguishes between recollection and automatic influences of memory.

Change detection and study times

Analyses of both the actual and log-transformed reaction times revealed no differences in the patterns of results. Consequently, only results from analyses of the actual reaction times are reported. The total List 2 presentation time, including the time it took participants to detect change and the time spent studying after change detection, is displayed in the top section of Table 3. The total presentation time was shorter for A–B, A–B items than for control items (4,080 vs. 5,138 ms), $t(39) = –6.30$, and shorter for control than for A–B, A–D items (5,138 vs. 6,180 ms), $t(39) = –6.45$. In addition, A–B, A–B items following two List 1 presentations were studied longer than those with four List 1 presentations (4,304 vs. 3,856 ms), $t(39) = 4.78$. Finally, we found no difference in the presentation times for A–B, A–D items between the two and four List 1 presentation conditions (6,186 vs. 6,175 ms), $t < 1$.

Table 3 Presentation time (in milliseconds) of List 2 items as a function of List 1 presentations and item type: Experiment 1

Item Type	**List 1 Presentations**	
	Two	**Four**
Total Presentation Time		
A–B, A–B	4,304 (427)	3,856 (378)
Control*	5,138 (477)	5,138 (477)
A–B, A–D	6,186 (534)	6,175 (563)
A–B, A–D Items		
No change detected	5,762 (590)	6,085 (671)
Time to detect change	4,139 (281)	3,856 (254)
Postchange detection study	2,423 (345)	2,396 (365)

*Control pairs were not subjected to the manipulation of List 1 presentations, so the times for those pairs presented in each column above are duplicates. For conditional analyses of A–B, A–D pairs in the lower panel, “No change detected” refers to the study time spent on pairs that were not identified as changed, “Time to detect change” refers to the time that it took participants to identify that pairs had changed responses, and “Postchange detection study” refers to the time that participants spent studying pairs after they had identified the pairs as changed. Standard errors of the means are presented in parentheses.

When the study time for A–B, A–D items was broken down by whether change was detected (bottom panel of Table 3), there were no significant differences between List 1 presentation conditions, *t*s < 1.49. However, examination of the overall presentation times revealed that more total time was spent for A–B, A–D items on which change was detected than when change was not detected (6,399 vs. 5,822 ms), $t(39) = 2.18$. These results suggest awareness of the occurrence of change, which is not surprising, given the task of explicitly indicating when change had occurred. However, it is possible that participants may have become aware of change even if they had not been instructed to indicate awareness of change. We examined this possibility in Experiment 2.

Item effects and recollection of change

One might argue that the measures of change detection and recollection reflect the selection of items whose cues are more easily recognized or more easily associated with other items. To examine the contribution of item differences, we performed a hierarchical multiple regression analysis at the item level with A–B, A–D recall performance as the dependent measure. We entered performance on control pairs in the first step of the model to measure the effect of item differences. Performance on control pairs served as an index of item differences because they only appeared in List 2, which precluded any item-specific influence of pairs from List 1. Furthermore, pairs were rotated through conditions such that pairs that served as A–D pairs for some participants served as control pairs for other participants. That is, across participants, a particular item represented each of the experimental conditions. After controlling for item differences, we examined the extent to which recollection of change accounted for unique variance in A–B, A–D recall by entering the probability of recollection of change as measured by the remindings-report procedure in the second step of the model. We examined the variance accounted for by the recollection-of-change measure instead of the change detection measure because the results revealed that facilitation depended on the recollection of change, which occurred almost exclusively following earlier detection of change. Finally, we entered an interaction term for these variables in the third step of the model.

Table 4 shows that although item differences accounted for variance in performance on A–B, A–D pairs (Step 1), recollection of change still predicted unique variance in A–B, A–D recall beyond item differences (Step 2). The interaction term did not predict unique variance in A–B, A–D recall (Step 3). These results show that although item differences do contribute to performance on A–B, A–D pairs, the detection and recollection of change plays a role beyond that of item differences in producing effects. Clearly, the results obtained by conditionalizing

List 2 recall in the A–B, A–D condition on recollection of change did not fully occur because of item selection effects.

Table 4 Proportions of variance in A–B, A–D recall performance explained by item differences and by recollection of change: Experiments 1–3

	Experiment		
	1	**2**	**3**
Step 1			
Item differences	.24*	.15*	.16*
Step 2			
Recollection of change	.16*	.27*	.41*
Step 3			
Item × Change interaction	.00	.01	.00

The values displayed above are changes in R^2 on each step of the model, computed at the item level collapsed across participants. “Item differences” refers to recall performance on control pairs, “Recollection of change” refers to the probability of participants’ reporting a List 1 response coming to mind first at test for A–B, A–D pairs, and “Item × Change interaction” is the interaction term for the aforementioned predictor variables. Data were collapsed across List 1 repetition conditions in Experiments 1 and 3. $^*p < .01$.

Individual differences and recollection of change

In addition to examining the relationship between item differences and A–B, A–D recall, we also examined the relationship between individual differences in participants’ general memory ability and A–B, A–D recall. We used a hierarchical multiple regression analysis that was the same as that used to examine item differences, with the exception that it was conducted at the participant level. In this model, performance on control pairs was taken as an index of the general memory ability of participants.

Table 5 shows that individual differences in general memory ability predicted performance on A–B, A–D pairs. However, when individual differences in general memory ability were controlled, recollection of change accounted for unique variance in A–B, A–D recall. That is, individual differences in the detection and recollection of change were also important for recall of A–B, A–D pairs. Similarly, results from prior research had suggested that individual differences in relating new to earlier studied information are important for later recall (e.g., Jacoby, 1974). The importance of individual differences in recollection of change provided additional evidence that the effects of conditionalizing List 2 recall on recollection of change did not fully occur because of item selection effects.

Table 5 Proportions of variance in A–B, A–D recall performance explained by individual differences and by recollection of change: Experiments 1–3

	Experiment		
	1	**2**	**3**
Step 1			
Individual differences	.26*	.71*	.40*

Step 2			
Recollection of change	.34*	.10*	.51*
Step 3			
Participant × Change interaction	.00	.00	.00

The values displayed above are changes in R^2 on each step of the model computed at the participant level, collapsed across items. “Individual differences” refers to recall performance on control pairs, “Recollection of change” refers to the probability of participants’ reporting a List 1 response coming to mind first at test for A–B, A–D pairs, and “Participant × Change interaction” is the interaction term for the aforementioned predictor variables. Data were collapsed across List 1 repetition conditions in Experiments 1 and 3. * $p < .01$.

Experiment 2

The results from Experiment 1 showed that recall performance did not differ between control and A–B, A–D pairs. These results were shown to reflect a mixture of proactive facilitation when change was recollected and proactive interference owing to automatic influences of memory when change was not recollected. Experiment 2 was designed to gain evidence that participants would covertly detect change for A–B, A–D pairs during the presentation of List 2 even when they were not instructed to do so overtly, as in Experiment 1. To do this, we allowed participants to self-pace their study in List 2 and employed the remindings-report procedure at test. This allowed us to back-sort study time on the basis of whether or not List 1 responses came to mind prior to the recalled responses at test. If change for A–B, A–D pairs was covertly detected during List 2 presentation, then study times for A–B, A–D items that eventuated in the production of List 1 responses prior to recall were expected to be longer than those for items for which no response was reported as coming to mind first.

Method

Participants

A group of 24 Washington University students participated in exchange for course credit or $10/h. All participants were tested individually.

Design, materials, and procedure

The design, materials, and procedure were the same as in Experiment 1, with the following exceptions. List 1 presentations were not manipulated; A–B pairs were presented three times each in List 1. The materials consisted of 88 of the three-word sets and four groups of buffers. These sets were assigned to within-participants conditions as in Experiment 1, except that an additional set of A–B control pairs were presented in List 1 that did not differ across the three experimental formats. Two groups of buffers were required for control pairs, because they differed in List 1 (A–B) and List 2 (C–D). List 1 consisted of 66 pairs (22 of each item type). There were 60 critical pairs, and the remaining six served as primacy and recency buffers in List 2. Pairs appeared three times, for 198 total presentations. List 2 also consisted of 66 pairs. In addition, three buffers appeared at the beginnings and ends of the lists to control for primacy and recency effects. Finally, six buffer items were used for a practice test.

In contrast to Experiment 1, participants were not required to indicate their detection of change, but rather were informed that for some items, the right-hand member of a pair would change between List 1 and List 2. Providing this information was meant to encourage covert detection of change.

Results and discussion

Table 1 shows that recall was better for A–B, A–B pairs than for controls (.83 vs. .64), $t(23) = 7.33$, and greater for control than for A–B, A–D pairs (.64 vs. .54), $t(23) = 4.17$. The finding of proactive interference in Experiment 2, but not in Experiment 1, might reflect a lower probability of remindings during the presentation of List 2 in Experiment 2. Consistent with this possibility, Table 2 shows that the probability of a List 1 response coming to mind first for A–B, A–D pairs in Experiment 2 was numerically lower than in Experiment 1. List 1 responses again made up the bulk of responses that came to mind first (76 %), with the remaining responses being from List 2 (10 %) or from outside of the experiment (14 %).

Just as was found in Experiment 1, when the remindings-report procedure showed that change was recollected, proactive facilitation was found. In contrast, when change was not recollected, proactive interference was found (Fig. 1). Recall was higher for A–B, A–D pairs when the List 1 response came to mind first, as compared to controls (.99 vs. .66), $t(22) = 8.32$, and higher for controls than for A–B, A–D pairs for which no response came to mind first (.66 vs. .35), $t(22) = 6.47$.

Analyses of both the actual and log-transformed reaction times revealed no differences in the patterns of results. Consequently, results from analyses of the actual reaction times are reported. Study time analyses showed that A–B, A–B pairs were studied for less time than were controls (4,330 vs. 5,106 ms), $t(23) = –3.07$, and that study times did not differ for control and A–B, A–D pairs (5,106 vs. 4,912 ms), $t < 1$. The finding that study times did not differ for A–B, A–D pairs and controls reflected a mixture of the presence and absence of remindings for A–B, A–D pairs. Analyses in which study time was back-sorted on the basis of reports of remindings at test provided evidence of covert detection of change for a subset of A–D pairs during List 2 presentation. A–D pairs for which the remindings-report procedure revealed that the List 1 response came to mind prior to output of the List 2 response were studied longer than were A–D pairs for which no other response was reported as coming to mind first (5,273 vs. 4,763 ms), $t(22) = 2.40$. This correspondence between recollection of change, as measured by the remindings-report procedure, and study time provides evidence of covert detection of change during List 2. More time during the presentation of List 2 was devoted to A–D pairs for which change was later recollected because detection of change requires time, and devoting any additional study time to those items required that change was detected.

Item effects and recollection of change

We examined the effects of item differences and recollection of change on A–B, A–D recall performance in the same manner as in Experiment 1. The results in Table 4 show convergence with those from Experiment 1 in demonstrating that although item differences accounted for unique variance in A–B, A–D recall performance, recollection of change accounted for variance above and beyond item differences. Again, the interaction term did not explain variance in A–B, A–D recall.

Individual differences and recollection of change

Also using the same analysis as in Experiment 1, we examined the effects of individual differences in general memory ability and recollection of change on A–B, A–D recall performance. Table 5 shows that, as in Experiment 1, general memory differences did account for variance in A–B, A–D recall, but recollection of change accounted for variance above and beyond those differences. The interaction term did not explain variance in A–B, A–D recall.

Experiment 3

The results from Experiments 1 and 2 provided evidence that recall of A–B, A–D pairs benefited from remindings, whether or not the remindings were overtly indicated. However, in both of the earlier experiments participants had self-paced their study, which may have allowed them to spend more time studying A–B, A–D pairs on which remindings occurred, resulting in increased performance on those pairs. We designed Experiment 3 to rule out this possibility by bringing List 2 study under experimenter control. Otherwise, the design of Experiment 3 was the same as that of Experiment 1. Despite the change to experimenter-controlled study times, we expected that the probability of remindings would again increase with List 1 presentations and that recall of A–B, A–D pairs would again reflect a mixture of facilitation and interference effects resulting from the presence and absence of remindings.

Method

Participants

A group of 25 Washington University students participated in exchange for course credit or $10/h. All participants were tested individually.

Design, materials, and procedure

The design, materials, and procedure were identical to those of Experiment 1, with the exception that there was no practice phase prior to List 2 presentation, List 2 no longer included the change detection measure, and the presentation duration in List 2 was fixed at 2 s per pair instead of being self-paced.

Results and discussion

As in the earlier experiments, Table 1 shows that the probability of recalling the List 2 response was higher for A–B, A–B than for control pairs (.73 vs. .41), $t(24) = 9.82$. Also, recall for A–B, A–B pairs was higher after four than after two List 1 presentations (.79 vs. .68), $t(24) = 3.45$. As we found in Experiment 1, performance on A–B, A–D pairs did not differ from that on control pairs (.41 vs. .41), $t < 1$. However, there was a marginally significant advantage for A–B, A–D pairs with four rather than two List 1 presentations (.44 vs. .38), $t(24) = 1.96$, $p = .06$. These results again point to offsetting facilitation and interference effects resulting from the presence and absence of remindings. In addition, the tendency for performance on A–B, A–D pairs to be higher following four than following two List 1 presentations suggests that more items in the former condition benefited from the facilitative effects of remindings.

Table 2 shows that the probability that a List 1 response was reported as having come to mind first was higher after four than after two List 1 presentations (.31 vs. .22), $t(24) = 2.84$, replicating the results of Experiment 1 by showing that remindings increased with the accessibility of List 1 responses. As is shown in Table 1, the probability of recall in Experiment 3 was lower for all conditions than in Experiment 1, which likely reflects the reduction in study time produced by bringing study time under experimenter control. The results in Table 2 show that List 1 responses were reported as coming to mind first less often in the present experiment than in Experiment 1 (.26 vs. .40), $F(1, 63) = 6.03$, $\eta_p^2 = .09$. This difference did not interact with the number of List 1 presentations, $F = 1.04$. As in the earlier experiments, List 1 responses comprised the majority of those reported as coming to mind first (73 %), whereas the remaining responses were from List 2 (11 %) or from outside the experiment (16 %).

Also in agreement with results from the earlier experiments (Fig. 1), List 2 recall was dramatically higher when a List 1 response was reported as coming to mind first, as compared to when no response was reported as coming to mind first (.93 vs. .24), $F(1, 20) = 471.25$, $\eta_p^2 = .96$. Neither the main effect of number of List 1 presentations nor its interaction with the effect of remindings was significant, *F*s < 1.88. The probability of recall was higher for A–B, A–D pairs for which the List 1 response was reported as coming to mind first than for controls (.93 vs. .41), $t(20) = 10.94$, and performance on controls was higher than on A–B, A–D pairs for which no response was reported as coming to mind first (.41 vs. .24), $t(20) = 5.37$. Comparing the results of Experiments 1 and 3, it is notable that the reduction in study time produced by its being brought under experimenter control in Experiment 3 reduced List 2 recall for control pairs and for pairs from the A–B, A–D condition for which recall was not preceded by a List 1 response coming to mind. In contrast, when List 2 recall was preceded by a List 1 response coming to mind, recall was somewhat higher in Experiment 3 than in Experiment 1. Clearly, the finding of proactive facilitation does not depend on the study time being under participant control, with a greater amount of study time being devoted to A–B, A–D pairs.

Item effects and recollection of change

As in Experiments 1 and 2, we examined the effects of item differences and recollection of change on A–B, A–D recall performance. The results in Table 4 again converge with those of the earlier experiments in showing that although item differences accounted for unique variance in A–B, A–D recall performance, recollection of change accounted for variance above and beyond item differences. Again, the interaction term did not explain variance in A–B, A–D recall.

Individual differences and recollection of change

Also using the same analysis as in Experiments 1 and 2, we examined effects of individual differences in general memory ability and recollection of change on A–B, A–D recall performance. Table 5 shows that, again, general memory differences did account for variance in

A–B, A–D recall, but recollection of change accounted for variance above and beyond those differences. The interaction term did not explain variance in A–B, A–D recall.

For each of our experiments, the results revealed that individual differences in recollection of change significantly contributed to the recall of List 2 responses. The magnitudes of the variance accounted for by general memory differences were larger in Experiment 3 than in the earlier experiments. This is understandable, because study time was experimenter-paced in Experiment 3, whereas study was self-paced in the earlier experiments. Self-paced study allowed for List 2 recall to be enhanced by means other than recollection of change, as evidenced by the differences in performance on control pairs across experiments. Retrieval based on these other origins reduced the contribution of individual differences in recollection of change to List 2 recall. Also, in contrast to Experiment 1, participants were not instructed to indicate change in Experiment 3, which afforded a greater opportunity for individual differences in self-initiated detection of change to contribute to List 2 recall.

General discussion

The results of our experiments show that recall of List 2 responses in an A–B, A–D paradigm reflects a mixture of proactive facilitation and proactive interference. The detection and recollection of change produces proactive facilitation when responses are changed across lists (A–B, A–D). Increasing the number of presentations of A–B had the effect of increasing the detection of change and, thereby, produced increased memory for A–D. In the absence of detection and recollection of change, prior presentation of A–B reduced later memory of A–D as compared to a control condition (i.e., proactive interference). When overt detection of change was not required, evidence of covert change detection was found (Exp. 2). Proactive facilitation was not diminished by bringing study time under experimenter control, although the resultant reduction in study time did reduce the probability of List 2 recall for control pairs and A–B, A–D pairs for which change was not recollected (Exp. 3). For each of the experiments, hierarchical multiple regression analyses revealed that recollection of change contributed to the correct recall of List 2 responses when item differences were controlled, showing that the results from analyses that relied on conditionalizing List 2 recall on recollection of change were not fully due to item selection effects.

The validity of our remindings-report procedure as a measure of recollection of change was supported by convergence of the results from that measure with those from the detection-of-change measure (Exp. 1). Increasing the number of presentations of A–B pairs increased the probability of detection of change for A–B, A–D pairs during presentation of List 2, and also increased the probability of the List 1 response being reported as having come to mind prior to the response that was recalled as having been presented in List 2, our measure of recollection of change. The List 2 response was more likely to be correctly recalled when change was detected during the presentation of List 2 than when it was not, which corresponds with the proactive facilitation that was observed when change was recollected at the time of test, as measured by the remindings-report procedure. Furthermore, when the List 1 response was recalled along with change detection during List 2, the List 1 response was very frequently reported as having come to mind prior to the response that was recalled as having come from List 2 on the later test, which almost never happened in the absence of the List 1 response being recalled along with change detection during List 2 presentation.

Others have attributed facilitation effects to memory of a List 2 response being mediated by memory for a List 1 response (e.g., Barnes & Underwood, 1959) and have explained proactive interference as resulting from response competition (e.g., Postman & Underwood, 1973). In contrast, we hold that proactive facilitation results from recollection of change that relies on the List 1 response being embedded in memory for the List 2 response due to recursive reminding. The recursive-reminding account of proactive facilitation effects holds an advantage over the mediation account in that it explains the importance of awareness of the relationship between List 1 and List 2 pairs for the finding of facilitation effects (e.g., R. B. Martin & Dean, 1964), whereas a mediation account does not do so.

According to our dual-process model, proactive facilitation results when change is recollected. When change is not recollected, proactive interference is produced by response competition that originates from reliance on a more automatic basis for responding. Arranging the situation so that opposite effects are produced by recollection and automatic influences, as was done by examining the effects of change, holds an advantage as a means of showing the existence of two bases for responding (e.g., Jacoby, 1991). The results of the present experiments converge with those from other experiments in providing support for a dual-process model of memory. For example, the results from Experiment 1 revealed that the retrieval of a List 1 response in the context of change detection produced facilitation when the change was later recollected, but increased proactive interference when the change was not. Similarly, Bishara and Jacoby (2008) found that practicing retrieval of a competing response increased proactive interference in an A–B, A–D paradigm, but did so only for older adults who have a reduced ability to recollect.

A critic might argue that our findings of proactive facilitation arose because the conditionalizing of List 2 recall on remindings serves to select items for which participants are able to remember the list membership of pairs. However, implicating the importance of list discrimination is of little value if one does not specify the basis for list discrimination. We hold that both list discrimination and recall of List 2 responses reflect recursive reminding involved in the detection of change. To support this position, Jacoby and Wahlheim (2012) employed procedures similar to those in the present experiments but examined the effects of detection of change on list discrimination rather than on recall of List 2 responses. Participants were asked to judge whether or not a test pair had earlier been presented in List 2. The results revealed that later list discrimination was near perfect following the detection of change in List 2, but much poorer if change was not detected. That is, the results for list discrimination parallel those found in the present experiments for List 2 recall.

The finding of parallel results between list discrimination and recall is unsurprising if both reflect reliance on the List 1 response being embedded in memory for the List 2 response as a result of recursive reminding. Also, list discrimination can be seen as closely related to recency judgments, which have been shown to be reliant on recursive reminding (e.g., Hintzman, 2011). Recency judgments typically require participants to judge the recency of items presented within a list, whereas list discrimination requires a between-list judgment of recency. Clearly, there are multiple bases for list discrimination, just as there are for recency judgments, including differences in memory strength and associations with list context (e.g., Hintzman, 2005; Kahana, Howard, & Polyn, 2008; Winograd, 1968), as well as recursive remindings. However, recursive remindings that accompany detection of change are a particularly important basis for list discrimination. Returning to the example of the self-contradicting politician used to begin this article, recursive remindings likely serve to both facilitate memory for the changed position and enhance memory for what the politician last claimed to believe, along with the contexts in which the conflicting beliefs were expressed.

The results reported here are related to results reported by Postman and Gray (1977). They manipulated the method of learning to examine effects on proactive interference in an A–B, A–D paradigm, using single letters paired with adjectives. Multiple study and test trials were employed for the learning of List 2. For test trials during List 2 learning in an “accretion” condition, participants were given a sheet of paper that listed the left-hand members of pairs as cues for recall of Lists 1 and 2. They were instructed to write the List 1 responses in one column and then to write the List 2 responses in an adjacent column. For a “replacement” condition, participants only recalled List 2 responses. Long-term retention of List 2 responses showed less proactive interference and superior list discrimination in the accretion condition as compared to the replacement condition. Postman and Gray attributed the reduction in proactive interference in the accretion condition to the improved list differentiation. The multiple recalls of List 1 along with List 2 responses in the accretion condition were said to provide repeated opportunities to note differences between the lists while practicing list discrimination. The resulting increase in the distinctiveness of “list tags” attached to memory for pairs was held to be responsible for the reduced proactive interference in the accretion condition. An account of that sort holds that list discrimination relies on simple associations and list tags, whereas we argue that list discrimination is preserved by memory for the relationship between A–B, A–D pairs in the form of a recursive representation (see Asch, 1969, for contrasts between the effects of simple associations and memory for higher-order relationships; see also Criss & Shiffrin, 2005, for evidence that list discrimination can rely on memory for higher-order relationships). Because of differences in the materials and procedures, the basis for list differentiation might differ between our experiment and that of Postman and Gray (1977).

Postman and Gray’s (1977) procedures did not allow them to investigate detection of the change in responses in the A–B, A–D condition. Consequently, they were unable to observe that awareness of the change in response was a critical determinant of whether proactive interference or proactive facilitation was observed. However, despite the numerous differences in procedures, our results agree with those reported by Postman and Gray in showing the benefit of bringing List 1 responses to mind in the presence of List 2 responses. In this vein, Sahakyan and Goodmon (2007) examined the effects of proactive interference on memory for lists of single words in a directed-forgetting paradigm. Their results revealed that the presence of associations between words in the two lists reduced proactive interference. They interpreted that finding as showing the benefit of List 1 items coming to mind during the presentation of List 2.

Here, we have focused on proactive effects of memory, but detection and recollection of change also likely play an important role in retroactive effects of memory. In line with this possibility, Loftus (1979) demonstrated the importance of conditions that lead to detection of change for eliminating misinformation effects (i.e., retroactive interference). In her experiments, participants were presented with a slide show of an event and were then tested on details from the slides. Following that, participants read a narrative about the event that included a few pieces of information that had been changed. The primary manipulation was whether a piece of blatantly contradictory information was included in the narrative. When a blatant contradiction was present, participants were able to notice it along with a large proportion of the other changed items. This resulted in their avoiding misinformation effects. In contrast, when a blatant contradiction was not present, the changed items went largely unnoticed, resulting in misinformation effects. These results are similar to the findings in the present experiments that detecting and recollecting change produced facilitation, whereas the failure to do so resulted in interference. Together, these studies highlight the importance of detecting change and the formation of embedded representations that include the reminding event and its constituents for both proactive and retroactive effects of memory.

Acknowledging the importance of detection and recollection of change is useful for explaining discrepancies across studies in the older literature that have examined proactive and retroactive effects of memory. Although A–B, A–D paradigms are typically used to investigate interference effects of changing the response paired with a cue, several studies have shown that changing responses does not always result in interference effects (e.g., Barnes & Underwood, 1959; Bruce & Weaver, 1973; Postman, 1964; Robbins & Bray, 1974). Anderson and McCulloch (1999) suggested that these discrepancies can be explained by differences in the extent to which conditions facilitated the integration of responses across lists. The advantage of a recursive-remindings framework is that it describes the mechanism by which the integration of responses is accomplished, with the mechanism being the detection and recollection of change.

Beyond proactive and retroactive effects demonstrated in paired-associate and misinformation paradigms, a recursive-remindings framework is applicable to domains examining effects on memory for more complex materials (cf. Benjamin & Ross, 2010). Returning to the earlier example of the politician who flip-flops, exploring memory for incongruent political statements would be informative about the extents to which people detect and recollect contradictions (cf. Glenberg & Epstein, 1987). Memory for change might also play an important role in memory for schema inconsistent information about people (cf. Hastie & Kumar, 1979). Furthermore, detection and recollection of change might be important for understanding the role of coherence in the construction and maintenance of mental models in text comprehension (cf. Albrecht & O'Brien, 1993). These are just a few examples that illustrate the potential importance of recursive remindings as an overarching framework for understanding phenomena across a broad range of domains that have otherwise been treated as largely separate.

Finally, the results from the present experiments revealed that individual differences in recollection of change predicted recall of List 2 responses. Such individual differences in the detection and recollection of change might be important for a variety of tasks, including the tasks described in the preceding paragraph. Evidence consistent with this suggestion was found by Zhu et al. (2010), who showed that individual differences in the susceptibility to misinformation effects (retroactive interference) correlated with differences in change detection in a perceptual task. Also, those who are less likely to detect and recollect change might be less likely to detect and recollect consistency among events. For example, Jacoby (1974) reported results pointing to the importance of individual differences in memory for categorically related information due to differences in looking back at information presented earlier during study. Similarly, Potts and colleagues (Potts, 1977; Potts, Keller, & Rooley, 1981; Potts & Peterson, 1985) have shown individual differences in the ability to integrate new learning with preexisting knowledge in linear-ordering tasks. Investigation of detection and recollection of change in the context of memory tasks has been largely neglected, but it holds promise as a means of investigating individual differences as well as proactive and retroactive effects of memory.

Notes

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References

1. Albrecht, J. E., & O’Brien, E. J. (1993). Updating a mental model: Maintaining both local and global coherence. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 19,* 1061–1070. doi: 10.1037/0278-7393.19.5.1061
2. Anderson, M. C., & McCulloch, K. C. (1999). Integration as a general boundary condition on retrieval-induced forgetting. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 25,* 608–629. doi: 10.1037/0278-7393.25.3.608
3. Appleton-Knapp, S. L., Bjork, R. A., & Wickens, T. D. (2005). Examining the spacing effect in advertising: Encoding variability, retrieval processes, and their interaction. *Journal of Consumer Research, 32,* 266–176.
4. Asch, S. E. (1969). A reformulation of the problem of associations. *American Psychologist, 24,* 92–102.
5. Barnes, J. M., & Underwood, B. J. (1959). “Fate” of first-list associations in transfer theory. *Journal of Experimental Psychology, 58,* 97–105. doi: 10.1037/h0047507
6. Benjamin, A. S., & Ross, B. H. (2010). The causes and consequences of reminding. In A. S. Benjamin (Ed.), *Successful remembering and successful forgetting: A Festschrift in honor of Robert A. Bjork* (pp. 71–87). New York: Psychology Press.
7. Benjamin, A. S., & Tullis, J. (2010). What makes distributed practice effective? *Cognitive Psychology, 61,* 228–247.

8. Bishara, A. J., & Jacoby, L. L. (2008). Aging, spaced retrieval, and inflexible memory performance. *Psychonomic Bulletin & Review, 15,* 52–57. doi: 10.3758/PBR.15.1.52

9. Bruce, D., & Weaver, G. E. (1973). Retroactive facilitation in short-term retention of minimally learned paired associates. *Journal of Experimental Psychology, 100,* 9–17.

10. Corballis, M. C. (2011). *The recursive mind: The origin of human language, thought, and civilization*. Princeton: Princeton University Press.

11. Criss, A. H., & Shiffrin, R. M. (2005). List discrimination in associative recognition and implications for representation. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 31,* 1199–1212.

12. Glenberg, A. M., & Epstein, W. (1987). Inexpert calibration of comprehension. *Memory & Cognition, 115,* 119–136.

13. Hall, J. F. (1971). *Verbal learning and retention*. Philadelphia: Lippincott.

14. Hastie, R., & Kumar, P. A. (1979). Person memory: Personality traits as organizing principles in memory for behaviors. *Journal of Personality and Social Psychology, 37,*25–38.

15. Hay, J. F., & Jacoby, L. L. (1999). Separating habit and recollection in young and older adults: Effects of elaborative processing and distinctiveness. *Psychology and Aging, 14,*122–134. doi: 10.1037/0882-7974.14.1.122

16. Hintzman, D. L. (2004). Judgment of frequency versus recognition confidence: Repetition and recursive reminding. *Memory & Cognition, 32,* 336–350. doi: 10.3758/BF03196863

17. Hintzman, D. L. (2005). Memory strength and recency judgments. *Psychonomic Bulletin & Review, 12,* 858–864. doi: 10.3758/BF03196777

18. Hintzman, D. L. (2010). How does repetition affect memory? Evidence from judgments of recency. *Memory & Cognition, 38,* 102–115. doi: 10.3758/MC.38.1.102

19. Hintzman, D. L. (2011). Research strategy in the study of memory: Fads, fallacies, and the search for the “coordinates of truth. *Perspectives on Psychological Science, 6,* 253–271. doi: 10.1177/1745691611406924

20. Huppert, F. A., & Piercy, M. (1978). The role of trace strength in recency and frequency judgments by amnesic and control subjects. *Quarterly Journal of Experimental Psychology, 30,* 347–354.

21. Jacoby, L. L. (1974). The role of mental contiguity in memory: Registration and retrieval effects. *Journal of Verbal Learning and Verbal Behavior, 13,* 483–496. doi: 10.1016/S0022-5371(74)80001-0

22. Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language, 30,* 513–541. doi: 10.1016/0749-596X(91)90025-F

23. Jacoby, L. L. (1996). Dissociating automatic and consciously controlled effects of study/test compatibility. *Journal of Memory and Language, 35,* 32–52.

24. Jacoby, L. L., & Wahlheim, C. N. (2012). Memory for change: The role of recursive remindings in list discrimination (source memory). Manuscript submitted for publication.

25. Johnston, W. A., & Uhl, C. N. (1976). The contributions of encoding effort and variability to the spacing effect on free recall. *Journal of Experimental Psychology: Human Learning and Memory, 2,* 153–160.

26. Kahana, M. J., Howard, M. W., & Polyn, S. M. (2008). Associative retrieval processes in episodic memory. In J. H. Byrne (Ed. in Chief) & H. L. Roediger III (Vol. Ed.), *Learning and memory: A comprehensive reference: Vol. 2. Cognitive psychology of memory* (pp. 467–490). Amsterdam, The Netherlands: Elsevier.

27. Kuhl, B. A., Shah, A. T., DuBrow, S., & Wagner, A. D. (2010). Resistance to forgetting associated with hippocampus-mediated reactivation during new learning. *Nature Neuroscience, 13,* 501–506.

28. Loftus, E. F. (1979). Reactions to blatantly contradictory information. *Memory & Cognition, 7*, 368–374.

29. Martin, E. (1968). Stimulus meaningfulness and paired-associate transfer: An encoding variability hypothesis. *Psychological Review, 75,* 421–441.

30. Martin, R. B., & Dean, S. J. (1964). Implicit and explicit mediation in paired-associate learning. *Journal of Experimental Psychology, 68,* 21–27.

31. Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (1998). The University of South Florida word association, rhyme, and word fragment norms. Retrieved from http://w3.usf.edu/FreeAssociation/

32. Postman, L. (1964). Studies of learning to learn: II. Changes in transfer as a function of practice. *Journal of Verbal Learning and Verbal Behavior, 3,* 437–447.

33. Postman, L., & Gray, W. (1977). Maintenance of prior associations and proactive inhibition. *Journal of Experimental Psychology: Human Learning and Memory, 3*, 255–263.

34. Postman, L., & Stark, K. (1969). Role of response availability in transfer and interference. *Journal of Experimental Psychology, 79,* 168–177.

35. Postman, L., & Underwood, B. J. (1973). Critical issues in interference theory. *Memory & Cognition*, *1,* 19–40.

36. Potts, G. R. (1977). Integrating new and old information. *Journal of Verbal Learning and Verbal Behavior, 16,* 305–320.

37. Potts, G. R., Keller, R. A., & Rooley, C. J. (1981). Factors affecting the use of world knowledge to complete a linear ordering. *Journal of Experimental Psychology: Human Learning and Memory, 7,* 254–268.

38. Potts, G. R., & Peterson, S. B. (1985). Incorporation versus compartmentalization in memory for discourse. *Journal of Memory and Language, 24,* 107–118.

39. Robbins, D., & Bray, J. F. (1974). Repetition effects and retroactive facilitation: Immediate and delayed test performance. *Bulletin of the Psychonomic Society, 3,* 347–349.

40. Russell, W. A., & Storms, L. H. (1955). Implicit verbal chaining in paired-associate learning. *Journal of Experimental Psychology, 49,* 287–293.

41. Sahakyan, L., & Goodmon, L. B. (2007). The influence of directional associations on directed forgetting and interference. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 33,* 1035–1049. doi: 10.1037/0278-7393.33.6.1035

42. Tzeng, O. J. L., & Cotton, B. (1980). A study-phase retrieval model of temporal coding. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 705–716.

43. Wichawut, C., & Martin, E. (1971). Independence of A–B and A–C associations in retroaction. *Journal of Verbal Learning and Verbal Behavior, 10,* 316–321.

44. Winograd, E. (1968). List differentiation, recall, and category similarity. *Journal of Experimental Psychology, 78,* 510–515.

45. Winograd, E., & Soloway, R. M. (1985). Reminding as a basis for temporal judgments. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 11,* 262–271.

46. Yonelinas, A. P., & Jacoby, L. L. (2012). The process-dissociation approach two decades later: Convergence, boundary conditions, and new directions. *Memory & Cognition, 40,*663–680. doi: 10.3758/s13421-012-0205-5

47. Young, R. K. (1955). Retroactive and proactive effects under varying condition of response similarity. *Journal of Experimental Psychology, 50,* 113–119.

48. Zhu, B., Chen, C., Loftus, E. F., Lin, C., He, Q., Chen, C., . . . Dong, Q. (2010). Individual differences in false memory from misinformation: Cognitive factors. *Memory, 18,* 543–555.